Original Article

Alveolar bone response to light-force tipping and bodily movement in maxillary incisor advancement: *A prospective randomized clinical trial*

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ABSTRACT

Objective: To compare alveolar bone thickness and height changes between untreated incisors (control), incisors advanced with light-force tipping, and incisors advanced with bodily movement mechanics.

Materials and Methods: Forty-three subjects (aged 9.49 $\pm$ 1.56 years) with anterior crossbite were allocated into an untreated group (control), tipping group, or bodily movement group. Lateral cephalograms were taken before advancement (T_0) and after obtaining normal overjet (T_1). Changes in labial and palatal alveolar bone thickness and height surrounding maxillary incisors were evaluated with limited field-of-view cone-beam computed tomography before advancement (CT_0) and 4 months after normal overjet was obtained (CT_1). Wilcoxon matched-pairs signed-rank and Kruskal-Wallis one-way ANOVA tests were used to compare changes within and between groups, as appropriate. The significance level was set at .05.

Results: Labial alveolar bone thickness at the midroot and apical levels were significantly decreased in the bodily movement group ($P < .05$). However, between groups, there was no statistically significant difference in labial bone thickness changes at any level. Palatal and total alveolar bone thickness at the midroot and apical levels were significantly decreased in the tipping group compared with the control and bodily movement groups ($P < .05$). Neither labial nor palatal bone height changes were significantly different among groups.

Conclusions: Maxillary incisor advancement with light-force tipping and bodily movement in growing patients resulted in labial alveolar bone thickness and labial and palatal alveolar bone height changes that were similar to the untreated group. (*Angle Orthod.* 2018;88:58–66.)

KEY WORDS: Alveolar bone thickness; Alveolar bone height; Tipping; Bodily movement; Light-force; Cone-beam computed tomography (CBCT)

INTRODUCTION

Maxillary incisor advancement is commonly achieved to correct an anterior crossbite.[1,2] If a round wire is used, the teeth will be advanced with uncontrolled tipping.[3] Labial root torque would be needed subsequently to obtain a better inclination.[1] Early use of a rectangular archwire may be more advantageous for controlling root inclination by moving teeth bodily.

Although several studies have reported the success of anterior crossbite correction by maxillary incisor advancement,[1,2] data on the appropriate magnitude of force is lacking. The level of optimal force for orthodontic tooth movement is still controversial.[4] Force exceeding the optimal level may produce several complications.[5–7] A recent cone-beam computed tomography (CBCT) study[3] revealed that force as

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Accepted: September 2017. Submitted: July 2017.
Published Online: October 30, 2017

 DOI: 10.2319/070717-449.1

light as 80 g could procline the four maxillary incisors while the surrounding alveolar bone was maintained and the rate of tooth movement was comparable to the rate of canine distalization with light force in another study.[8]

Different types of loading force (moment-to-force ratios) produce different types of tooth movement.[9] Uncontrolled tipping generates stress at the apex and alveolar crest, whereas tooth movement with root torque creates uniformly distributed stresses along the entire compressed periodontal surface, resulting in bodily movement or translation.[10] Also, the bone remodeling-to-tooth movement (B/T) ratios in different types of tooth movement have been shown to be different.[11]

A recent CBCT study found that the change in incisor inclination during retraction was a significant factor influencing the change of alveolar bone thickness, which, at the crestal area, was strongly and positively correlated with upper incisor retraction with tipping.[12] Alveolar bone response when light force is used to produce different types of tooth movement has never been reported. The purpose of this study was to test the null hypothesis that there is no difference in alveolar bone thickness and height changes between untreated and treated patients after incisor advancement with either light tipping or bodily movement.

MATERIALS AND METHODS

Subjects

This prospective randomized clinical trial was approved by the Ethics Committee on Human Research of the Faculty of Dentistry, Prince of Songkla University (ethical approval No. EC5803-08-P-HR). The sample size was calculated by G*Power (Version 3.1)[13] using parameters from a pilot study on alveolar bone thickness changes with different light-force advancing mechanics (the difference of mean of untreated, tipping, and bodily advancement = –0.13, –0.28, and 0.06 mm, respectively; the difference of standard deviations = 0.28 mm, significance level = .05, power = 0.80). A sample size of 15 per group was required.

Subjects were recruited between June 2013 and August 2015. The inclusion criteria were prepubertal growth status as assessed by hand-wrist radiographic examination (PP2-MP3cap),[14] anterior crossbite in maximum intercuspation, good general and oral health, and no signs or symptoms of traumatic occlusion. Exclusion criteria were history of trauma to the maxillary incisors or use of anti-inflammatory drugs within 6 months before treatment. All parents of subjects were informed, and written informed consent was signed before participating in the study.

Treatment Protocol

Using the card shuffling method,[15] subjects were randomly divided into three groups: control, tipping, and bodily movement. Those in the control group were monitored and observed for dental changes, alveolar bone thickness, and height changes for an average of 10 months and then underwent comprehensive orthodontic care. Subjects in the experimental groups were treated with 2 × 4 appliances (Roth preadjusted edgewise appliances; Ormco Corp, Glendora, Calif), which consisted of 0.018 × 0.025-inch brackets on the four maxillary incisors and buccal tubes with 0.022 × 0.028-inch slots on the maxillary first molars. The maxillary incisors of only the bodily movement group were bonded upside down to enhance torque control for bodily movement during advancement. To reduce interferences that might impede tooth movement in the crossbite area, a thin layer of light-cured compomer (Ultra Band-lok, Reliance Orthodontic Products, Inc, Itasca, Ill) was applied to the occlusal surfaces of the lower molars. The maxillary incisors were aligned using sequential segments of 0.012-inch NiTi to 0.016-inch NiTi wire on the incisors only, and they were ligated together.

For the tipping group, the maxillary incisors were advanced using 0.016-inch titanium-molybdenum alloy (TMA) wire with *U*-shaped advancing loops (3mm height and width) that pushed against the mesial surface of the molar buccal tubes (Figure 1A,B). Subjects in the bodily movement group were treated with 0.016 × 0.022-inch TMA with bulb-shaped advancing loops (6 mm height and width; Figure 1C,D). A force gauge was used at each visit to confirm that 80 g of anterior force was obtained with loop activation in both groups. Archwires were secured in place with stainless steel ligature wires. Loops were activated every 4 weeks until normal overjet was obtained. Subsequently, the same, unactivated archwire was used to maintain the position of the maxillary incisors for 4 months to allow for osteogenesis.[10] During the 4-month retention period, subjects were examined every month for stability of overjet and control of oral hygiene. Subjects were informed that if wire breakage occurred, they were to have it replaced within 1 day.

Lateral Cephalometric Analysis

For the control group, lateral cephalograms were taken before (T_0) and at the end of the observation period (T_1). For the experimental groups, lateral cephalograms were taken before maxillary incisor advancement (T_0) and after achieving normal overjet (T_1). The same cephalostat and cephalometric machine were used for all lateral cephalograms. Cephalometric radiographs were traced on acetate paper using a 0.3-mm mechanical pencil. Cephalometric

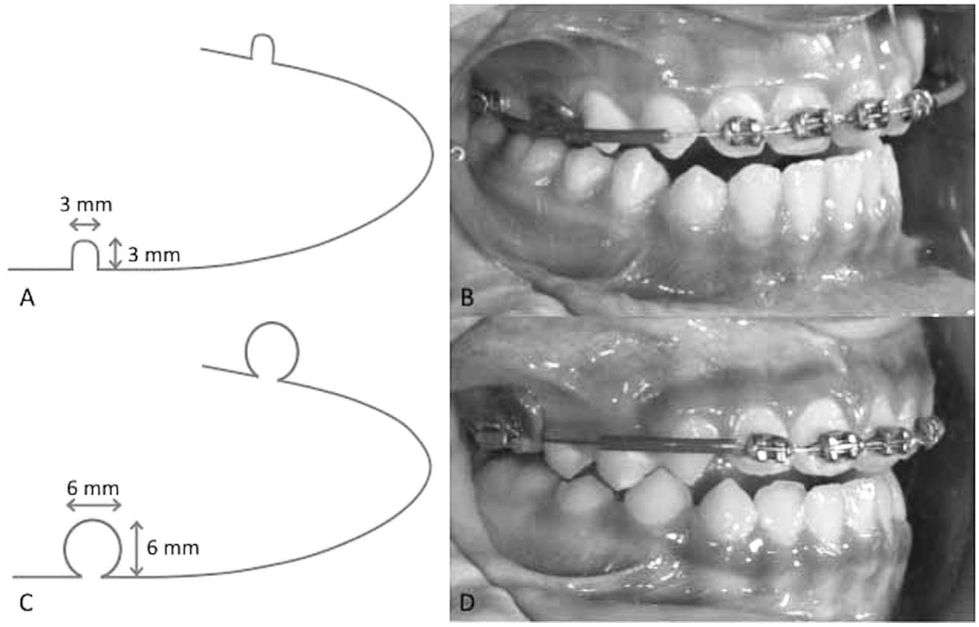

Figure 1. (A,B) Design diagram and intraoral photo of 0.016-inch TMA wire with *U*-loops for maxillary incisor advancement in the tipping group. (C,D) Design diagram and intraoral photo of 0.016 × 0.022-inch TMA with bulbous loops for maxillary incisor advancement in the bodily movement group.

analysis was based on the method of Pancherz.[16] The horizontal reference plane (HP) was constructed 6° down from the S-N plane; the vertical reference plane (VP) was perpendicular to HP at sella. Perpendicular lines from three reference points: A-point, incisal edge of the maxillary incisor (MxI), and apex of the maxillary incisor (MxIapex), were measured to both HP and VP (Figure 2). Additionally, the inclination of the maxillary incisor to the palatal plane (MxI-PP) was measured. The changes in MxI to VP of the tipping and bodily movement groups were used to calculate the rate of maxillary incisor advancement with tipping and bodily movement.

CBCT Analysis

CBCT images were obtained using the smallest field of view (FOV) that was large enough to cover the four maxillary incisors (Veraviewepocs, J Morita MPG, Kyoto, Japan); 80 kV, 5 mA, 7.5-second exposure time, 0.125-mm voxel resolution, and 80 × 40-mm FOV). In the control group, CBCTs were taken before (CT_0) and after the period of observation (CT_1). In the experimental groups, CBCTs were taken before maxillary incisor advancement (CT_0) and 4 months after normal overjet was achieved (CT_1). One Volume Viewer software (Version 11.0, Dolphin Imaging and Management Solutions, Chatsworth, Calif) was used to measure alveolar bone thickness and height of all four maxillary incisors. The alveolar bone thickness assessment was based on Sarikaya et al.[17] Measurements were taken at the site adjacent to the widest labiopalatal point of the maxillary incisor roots. Each tooth was measured at three levels apical to the cementoenamel junction (CEJ) at every 3 mm along the long axis of the tooth: crestal, midroot, and apical levels (S1, S2, and S3, respectively; Figure 3A). Labial, palatal, and total bone thickness was measured at every level (L1, L2, L3, P1, P2, P3 and T1, T2, T3, respectively; Figure 3B). Labial and palatal alveolar bone heights (LABH and PABH) were assessed with the CEJ and the alveolar crest as landmarks for measurement. Alveolar bone height was the vertical linear distance between the CEJ and alveolar crest measured along the long axis of the tooth (Figure 4).[18] The data obtained from alveolar bone thickness and height of the four maxillary incisors were averaged and used for statistical analysis.

Statistical Analysis

Shapiro-Wilk tests showed that the data were skewed. Consequently, Wilcoxon matched-pairs signed-rank tests were used to evaluate the within-group changes. Kruskal-Wallis one-way ANOVA was used to compare the between-group changes. Dunn-Bonferroni was used for post hoc evaluation. Mann-Whitney *U*-tests were used to compare differences between the two experimental groups. All cephalometric and CBCT data were measured by one investigator. All data were measured twice at an interval of 4 weeks. Dahlberg's formula[19] was used to assess measurement error. Intra-observer reliability of the measure-

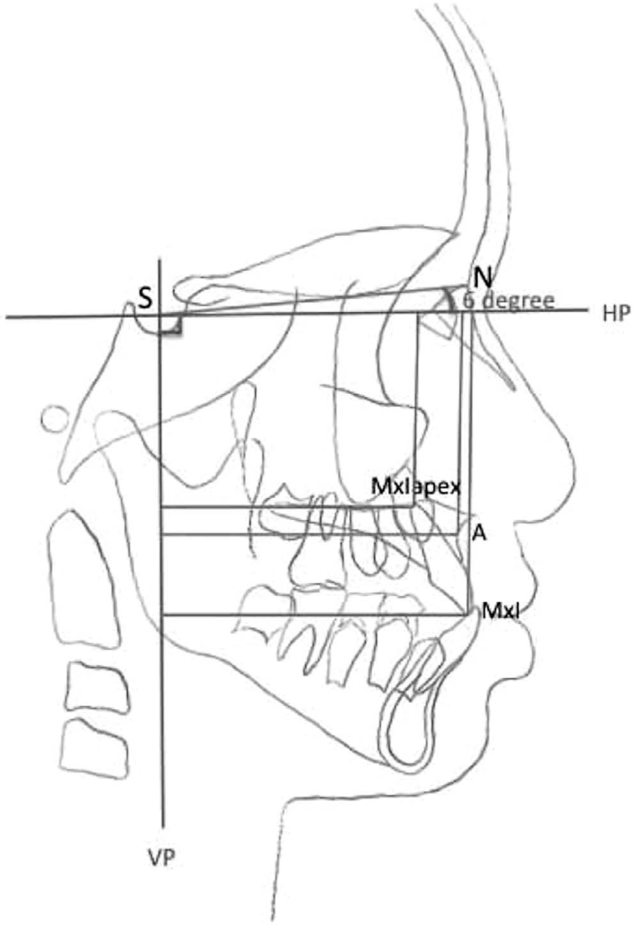

Figure 2. Cephalometric reference planes and points used in this study.

Figure 4. Labial and palatal alveolar bone height measurements.

ments was assessed using paired *t*-tests. The significance level of all tests was established at .05.

RESULTS

The measurement error for each parameter was found to be less than 0.5 mm for linear and 0.5° for angular variables. Paired *t*-tests showed no significant

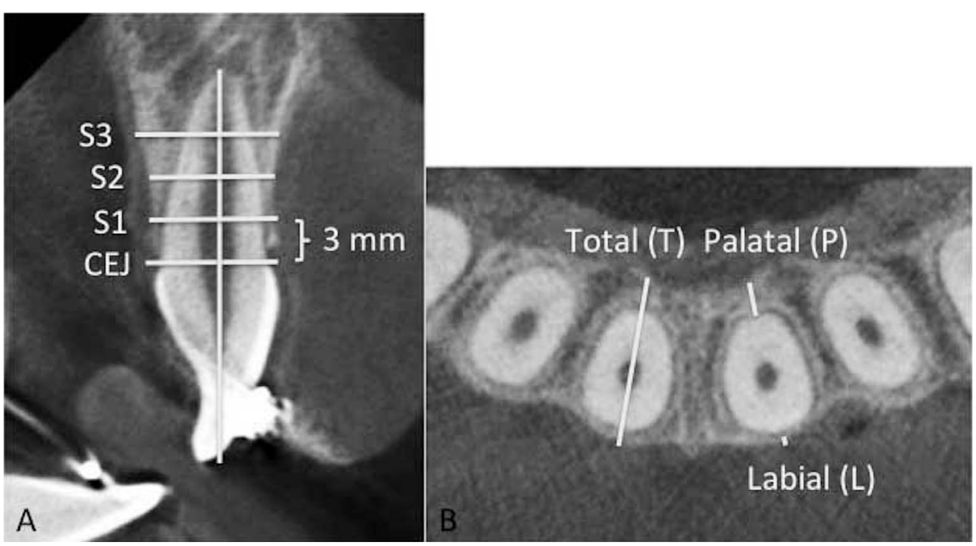

Figure 3. (A) The three vertical levels of alveolar bone thickness measurement. (B) Labial, palatal, and total alveolar bone thickness measurements.

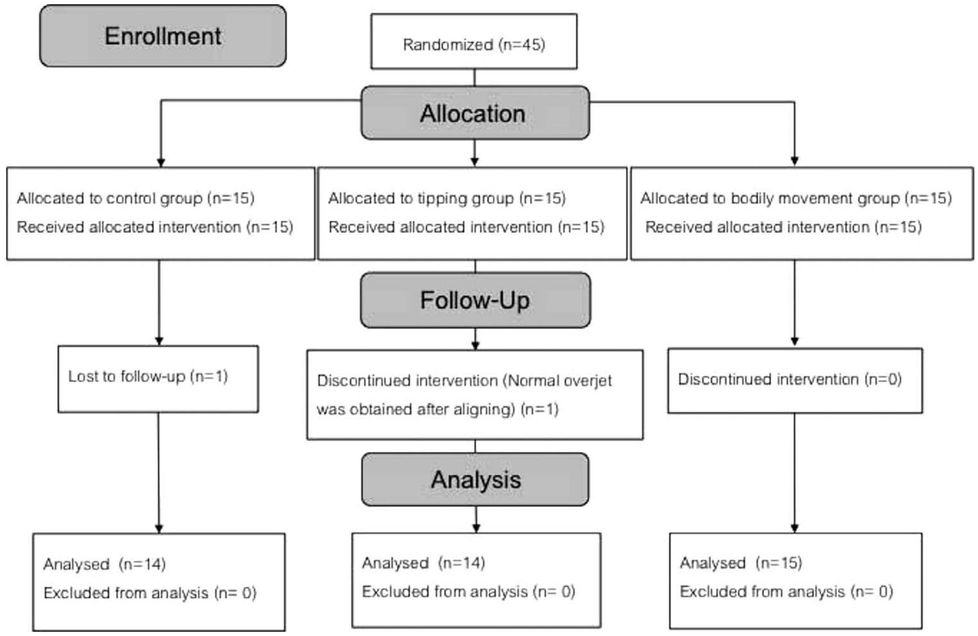

Figure 5. CONSORT flow diagram of participants through each stage of the trial.

differences between the two series of measurements made 4 weeks apart, showing that the measurements were reliable.

The CONSORT diagram shows the flow of subjects through the trial (Figure 5). Of the 45 subjects participating in the study, one subject was lost from the control group due to loss of contact before the end of the observation period and one was lost from the tipping group because normal overjet was obtained after alignment. Table 1 shows the number, age, and cephalometric characteristics of the subjects among groups. There were no statistically significant differences in any parameter among the three groups before treatment. ($P \geq .05$).

There were no statistically significant differences between total observation/treatment times among the three groups ($P \geq .05$). Alignment time, advancement time, and rate of incisor advancement were not significantly different between the tipping and bodily movement groups ($P \geq .05$; Table 2).

A-point and the maxillary incisal edge moved forward and downward significantly in both treatment groups ($P < .05$), whereas A-point remained unchanged horizontally in the control group ($P \geq .05$). Maxillary incisor inclination significantly increased in the tipping group ($P < .05$) but did not change significantly in either the control or bodily movement groups ($P \geq .05$; Table 3).

Compared with the control group, forward movement of A-point was significantly greater in the bodily movement group ($P < .05$). Dentally, forward movement of the maxillary incisors was significantly greater in both treatment groups compared with the control group ($P < .05$). Forward movement of the maxillary incisor apex was significantly greater in the bodily movement group ($P < .05$). Maxillary incisor inclination change was significantly greater in the tipping group ($P < .05$; Table 4).

Tables 5 and 6 show the within- and between-group changes in alveolar bone thickness and height, respectively. In the control group, significant decreases in bone thickness at the crestal and midroot levels on the labial side were observed ($P < .05$). In the bodily movement group, labial bone thickness at the midroot and apical levels decreased significantly ($P < .05$), whereas palatal bone thickness decreased significantly in the tipping group ($P < .05$). There were no differences in labial bone thickness changes among the groups ($P \geq .05$). Labial and palatal bone heights were maintained in all groups ($P \geq .05$).

Table 1. Comparison of Pretreatment Morphology Between the Three Groups

	Control (n = 14)		Tipping (n = 14)		Bodily (n = 15)		
Variable	Mean	SD[a]	Mean	SD	Mean	SD	*P* Value[b]
n (boys:girls)	7:7		4:10		11:4		
Age (y)	9.79	1.42	8.79	1.12	9.87	1.88	.141
ANB (°)	−1.96	3.68	0.57	2.23	−0.43	2.29	.123
MxI-PP (°)	119.07	6.20	112.43	9.48	117.87	9.26	.121
Overjet (mm)	−1.46	2.19	−1.54	1.62	−2.17	2.12	.485

[a] SD indicates standard deviation.
[b] *P* value of Kruskal-Wallis one-way ANOVA.

Table 2. Means and Standard Deviations of Total Observation/Treatment Time, Alignment Time, Incisor Advancement Time, and Rate of Incisor Advancement

Variable	Control (n = 14) Mean	SD[a]	Tipping (n = 14) Mean	SD	Bodily (n = 15) Mean	SD	*P* Value
Total observ/trt time (mo)	10.18	2.83	10.07	2.64	9.73	4.57	.895[b]
Alignment time (mo)	–	–	4.64	1.22	5.53	3.14	.331[c]
Advancement time (mo)	–	–	5.43	2.65	4.20	2.21	.216[c]
Rate of incisor advancement (mm/mo)	–	–	1.05	0.49	1.10	0.60	.725[c]

[a] SD indicates standard deviation.
[b] *P* value of Kruskal-Wallis one-way ANOVA.
[c] *P* value of Mann-Whitney *U*-tests.

DISCUSSION

This study found that the treatment groups (tipping and bodily movement) experienced amounts of labial bone thickness changes similar to that of the control group. However, the amount of palatal bone thickness reduction of the tipping group was significantly greater than those of the control and bodily movement groups. No significant changes in bone height were found in any of the groups.

The prescribed mechanics produced incisor advancement with both tipping and bodily movements as planned. With round wire, the incisors tipped 10.7°, while the rectangular wire in combination with upside-down brackets moved both the crown and root forward with as little as 0.1° of inclination change.

Generally, tooth movement by tipping is faster than bodily movement.[20] However, this was not observed in our study. The rates of advancement between the tipping and bodily movement groups were not substantially different (1.05 vs 1.10 mm/mo). During the study, the incidence of round wire breakage was higher than for rectangular wire (percent breakage = 64.3% vs 33.3% of patients with at least one wire broken; 17.1% vs 8.0% of total wires broken). This may have led to discontinuity of applied force in the tipping group. Additionally, due to the low stiffness of round wire and because the point of anterior force application was at the lateral incisors from the compressed loop, the anterior curvature of the arch flattened with treatment. The central incisors were therefore advanced less than the lateral incisors, especially in the tipping group.

The decrease in bone thickness at L1 and L2 observed in the untreated control group was not surprising since resorption of the anterior surface of the maxilla is known to occur during normal maxillary growth, along with downward and forward movement of the maxillary complex.[21] The current study also found that labial bone thickness was maintained during incisor advancement with light tipping force, which is in agreement with a similar previous study.[3] In contrast, the labial bone thickness in some areas decreased significantly in the bodily movement group. However, these changes were not significantly different from changes observed in the untreated or tipping groups.

In agreement with a previous study,[3] the palatal bone thickness of the tipping group decreased significantly compared with the control group. There are three possible hypotheses to account for this. First, when a maxillary anterior tooth is tipped labially, compression occurs on the palatal aspect of the apex and on the labial alveolar crest. Since the apex has less surface

Table 3. Mean Cephalometric Values and Differences Before (T_0) and After (T_1) Observation Period of Control Group and Before (T_0) and After (T_1) Incisor Advancement for the Tipping and Bodily Movement Groups

	Control (n = 14)					Tipping (n=14)					Bodily (n = 15)				
	T_0		T_1			T_0		T_1			T_0		T_1		
Variable	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
Horizontal measurement (mm)															
A-VP	64.14	5.63	64.68	5.50	.068	61.39	4.48	62.36	3.77	.044*	63.93	4.40	65.80	4.71	.001*
MxI-VP	69.43	7.51	70.79	7.05	.038*	64.32	7.61	70.00	6.54	.001*	68.43	6.16	72.37	6.58	.001*
MxIapex-VP	57.21	5.54	57.96	5.39	.117	55.50	5.02	56.57	4.43	.174	56.90	3.68	60.50	4.71	.001*
Vertical measurement (mm)															
A-HP	48.04	3.89	49.89	4.77	.004*	48.07	3.27	49.57	4.63	.007*	49.17	3.26	50.03	3.44	.007*
MxI-HP	69.71	5.09	71.89	5.29	.001*	70.07	3.89	72.04	4.95	.002*	71.73	3.70	72.57	4.13	.002*
MxIapex-HP	46.36	4.20	49.54	5.93	.001*	44.93	4.00	49.29	5.14	.001*	46.63	3.76	48.93	4.08	.001*
Angular measurement (°)															
MxI-PP	119.07	6.20	120.14	5.52	.165	112.43	9.48	123.11	5.76	.001*	117.87	9.26	117.97	7.05	.977

[a] SD indicates standard deviation.
* Significant at $P < .05$ by Wilcoxon matched-pairs signed-rank tests.

Table 4. Comparison of Means and Standard Deviations of Cephalometric Value Changes Between the Three Groups

Variable	T_1-T_0 Control (n = 14)		T_1-T_0 Tipping (n = 14)		T_1-T_0 Bodily (n = 15)		
	Mean	SD	Mean	SD	Mean	SD	*P* Value
Horizontal measurement (mm)							
A-VP	0.54[a]	0.97	0.96[a,b]	1.69	1.87[b]	1.29	.012*
MxI-VP	1.36	2.13	5.68[a]	3.31	3.93[a]	1.87	.001*
MxIapex-VP	0.75[a]	1.61	1.07[a]	2.45	3.60	2.11	.001*
Vertical measurement (mm)							
A-HP	1.86	1.76	1.50	1.68	0.87	0.93	.231
MxI-HP	2.18	0.91	1.96	1.99	1.83	1.60	.466
MxIapex-HP	3.18	2.76	4.36	2.93	2.30	1.65	.072
Angular measurement (°)							
MxI-PP	1.07[a]	2.46	10.68	8.24	0.10[a]	3.58	0.000*

* Significant at $P < .05$ by Kruskal-Wallis one-way ANOVA.
[a] Groups with the same letter are not significantly different ($P > .05$); SD indicates standard deviation.

area than root surface at alveolar crest, the amount of force per compressed area was higher and may have resulted in increased resorption. Second, a generally slower remodeling process may occur on the palatal side. Third, when the tooth tipped, the geometry of measurement changed and the distance from the palatal surface perpendicular to the root axis became shorter.

In this study, the vertical dental changes in the treatment groups were not different than those observed in the control group. Therefore, it can be assumed that neither the extrusion of the teeth nor the alveolar bone height changes were due to orthodontic mechanics. There was no evidence of loss of the alveolar crest in either of the treatment groups. In contrast, a study in nongrowing monkeys reported marginal bone loss after mandibular incisor protraction.[22] In that study, 100 g of force was used to advance two mandibular incisors. A high bone turnover rate in growing subjects and the use of light force in the current study may have helped maintain the labial alveolar crest. This is supported by a previously published report of using light force to promote bone deposition and improve an alveolar defect.[23]

Based on the results observed, light force produced favorable and safe incisor advancement in growing patients regardless of the wire type used. Tipping with round wire could be used in patients with retroclined maxillary incisors, while bodily movement for advancement can be more beneficial for a patient who has normally inclined or proclined maxillary incisors. Incisor advancement should be done with caution in patients who have thin labial alveolar bone.

Using the tooth axis as a reference for making bone thickness and height measurements is an accepted method that has been used frequently in previous studies.[3,17,18] However, there are geometric limitations that should be considered. When the tooth axis changes, the directions in which the measurements are made change as well. The more the tooth is

Table 5. Comparison of Means and Standard Deviations of Averaged Alveolar Bone Thickness and Height of the Four Maxillary Incisors Before (CT_0) and After (CT_1) Growth Observation of the Control Group and Before (CT_0) and 4 Months After (CT_1) Achieving Normal Overjet of the Tipping and Bodily Movement Groups

Variables	Control (n = 14)					Tipping (n = 14)					Bodily (n = 15)				
	CT_0		CT_1		*P*	CT_0		CT_1		*P*	CT_0		CT_1		*P*
	Mean	SD	Mean	SD	Value	Mean	SD	Mean	SD	Value	Mean	SD	Mean	SD	Value
Alveolar bone thickness (mm)															
L1	0.61	0.20	0.54	0.19	.023*	0.61	0.26	0.63	0.20	.624	0.53	0.24	0.52	0.20	.712
L2	0.76	0.30	0.63	0.33	.048*	0.80	0.51	0.72	0.32	.470	0.75	0.41	0.57	0.28	.033*
L3	1.55	0.84	1.42	0.82	.272	1.68	0.75	1.57	0.75	.363	1.41	0.63	1.11	0.58	.011*
P1	1.47	0.41	1.33	0.43	.149	1.56	0.78	1.28	0.78	.013*	1.74	0.93	1.69	0.75	.629
P2	2.73	0.61	2.51	0.65	.140	2.80	1.03	1.91	0.98	.001*	2.61	1.26	3.03	1.24	.031*
P3	4.06	0.82	4.07	0.85	.826	4.18	1.26	2.69	1.08	.003*	3.88	1.66	4.31	1.55	.233
T1	8.22	0.74	7.97	0.71	.060	8.31	1.08	8.05	0.93	.074	8.34	1.39	8.07	1.06	.427
T2	9.02	0.86	8.66	0.96	.022*	9.06	1.55	8.07	1.38	.001*	8.84	1.86	8.68	1.70	.426
T3	10.13	0.75	9.83	1.07	.055	10.16	1.84	8.51	1.95	.001*	9.93	2.37	9.40	2.24	.100
Alveolar bone height (mm)															
LABH	0.62	0.27	0.66	0.24	.151	0.51	0.28	0.55	0.26	.650	0.52	0.40	0.65	0.41	.057
PABH	0.59	0.22	0.60	0.19	.851	0.46	0.36	0.49	0.19	.777	0.71	0.69	0.63	0.57	.443

* Significant at $P < .05$ by Wilcoxon matched-pairs signed-rank tests; SD indicates standard deviation.

Table 6. Comparison of Means and Standard Deviations of Averaged Alveolar Bone Thickness and Height Changes of the Four Maxillary Incisors Between the Three Groups

	CT_1-CT_0 Control (n = 14)		CT_1-CT_0 Tipping (n = 14)		CT_1-CT_0 Bodily Movement (n = 15)		
Variables	Mean	SD	Mean	SD	Mean	SD	*P* Value
Alveolar bone thickness (mm)							
L1	−0.07	0.10	0.03	0.21	−0.01	0.23	.139
L2	−0.12	0.21	−0.08	0.27	−0.18	0.32	.600
L3	−0.13	0.41	−0.10	0.27	−0.30	0.38	.366
P1	−0.14	0.41	−0.28	0.70	−0.05	0.66	.103
P2	−0.23[a]	0.59	−0.89	0.66	0.42[a]	0.68	.000*
P3	0.01[a]	0.58	−1.48	1.22	0.43[a]	1.18	.000*
T1	−0.26	0.44	−0.26	0.66	−0.27	0.81	.814
T2	−0.36[a]	0.50	−0.98	0.64	−0.16[a]	0.65	.007*
T3	−0.30[a]	0.51	−1.66	1.12	−0.53[a]	1.05	.005*
Alveolar bone height (mm)							
LABH	0.03	0.29	0.04	0.26	0.12	0.22	.396
PABH	0.01	0.18	0.03	0.29	−0.08	0.35	.694

* Significant at $P < .05$ by Kruskal-Wallis one-way ANOVA; SD indicates standard deviation.
[a] Groups with the same letter are not significantly different ($P > .05$).

tipped, the greater the probability that this will affect the measurements. However, the thickness and height of bone surrounding a tooth are important measures with clinical relevance, regardless of the tooth's inclination. Lastly, since the current study evaluated alveolar bone changes 4 months after tooth movement was accomplished, it would be important for future studies to examine changes over a longer period.

CONCLUSIONS

When the maxillary incisors were advanced using light forces for tipping or bodily movement in growing patients, the following conclusions were drawn:

- The labial alveolar bone thickness was maintained whether teeth were advanced by tipping or bodily movement compared with an untreated group.
- Compared with an untreated group, the palatal and total alveolar bone thickness at the midroot and apical levels were decreased in the tipping group but not in the bodily movement group.
- The labial and palatal alveolar bone heights were maintained in both the tipping and bodily movement groups.

ACKNOWLEDGMENTS

We would like to thank the Graduate School and the Faculty of Dentistry, Prince of Songkla University, for grant support.

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